



## Books & Reports

### **Stable Satellite Orbits for Global Coverage of the Moon**

A document proposes a constellation of spacecraft to be placed in orbit around the Moon to provide navigation and communication services with global coverage required for exploration of the Moon. There would be six spacecraft in inclined elliptical orbits: three in each of two orthogonal orbital planes, suggestive of a linked-chain configuration. The orbits have been chosen to (1) provide 99.999-percent global coverage for ten years and (2) to be stable under perturbation by Earth gravitation and solar-radiation pressure, so that no deterministic firing of thrusters would be needed to maintain the orbits. However, a minor amount of orbit control might be needed to correct for such unmodeled effects as outgassing of the spacecraft.

*This work was done by Todd Ely of Caltech and Erica Lieb of ASRC for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42722*

### **Low-Cost Propellant Launch From a Tethered Balloon**

A document presents a concept for relatively inexpensive delivery of propellant to a large fuel depot in low orbit around the Earth, for use in rockets destined for higher orbits, the Moon, and for remote planets. The propellant is expected to be at least 85 percent of the mass needed in low Earth orbit to support the NASA Exploration Vision. The concept calls for the use of many small ( $\approx 10$  ton) spin-stabilized, multistage, solid-fuel rockets to each deliver  $\approx 250$  kg of propellant. Each rocket would be winched up to a balloon tethered above most of the atmospheric mass (optimal altitude  $26 \pm 2$  km). There, the rocket would be aimed slightly above the horizon, spun, dropped, and fired at a time chosen so that the rocket would arrive in orbit near the depot. Small thrusters on the payload (powered, for example, by boil-off gasses from cryogenic propellants that make up the

payload) would precess the spinning rocket, using data from a low-cost inertial sensor to correct for small aerodynamic and solid rocket nozzle misalignment torques on the spinning rocket; would manage the angle of attack and the final orbit insertion burn; and would be fired on command from the depot in response to observations of the trajectory of the payload so as to make small corrections to bring the payload into a rendezvous orbit and despin it for capture by the depot. The system is low-cost because the small rockets can be mass-produced using the same techniques as those to produce automobiles and low-cost munitions, and one or more can be launched from a U.S. territory on the equator (Baker or Jarvis Islands in the mid-Pacific) to the fuel depot on each orbit (every 90 minutes, e.g., any multiple of 6,000 per year).

*This work was done by Brian Wilcox of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42007*